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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The research reported here was concerned with the investigation of approximation techniques for identification of control systems governed by functional differential equations. The work was primarily concerned with retarded systems, although some effort was devoted to neutral systems. Throughout the research, the objective was the development of efficient computational algorithms for parameter estimation in linear and nonlinear hereditary systems. The investigations were based on state space formulations of hereditary dynamics, on corresponding approximation

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20. ABSTRACT CONTINUED

techniques and on finite difference methods. The results obtained are applicable to a large class of dynamical processes with memory, including certain aero-elastic problems, biological feedback systems, feedback control systems, visco-elastic problems and mechanical systems with retardation.

IDENTIFICATION OF HEREDITARY CONTROL SYSTEMS VIA APPROXIMATION TECHNIQUES

A FINAL REPORT ON GRANTS

DAAG-29-78-G-0125

continued as

DAAG-29-80-C-0126

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November, 1981

1. SUMMARY

During the period 1 June, 1978 to 30 September, 1981, this research was supported by the U.S. Army Research Office under grant DAAG-29-78-G-0125 and the following contract DAAG-29-80-C-0126. The research was concerned with the investigation of approximation techniques for identification of control systems governed by functional differential equations.

The work was primarily concerned with retarded systems, although some effort was devoted to neutral systems. Throughout the research, the objective was the development of efficient computational algorithms for parameter estimation in linear and nonlinear hereditary systems. The investigations were based on state space formulations of hereditary dynamics, on corresponding approximations techniques and on finite difference methods.

The results obtained are applicable to a large class of dynamical processes with memory, including certain aero-elastic problems, biological feedback systems, feedback control systems, visco-elastic problems and mechanical systems with retardation.

The research supported by this grant resulted in eleven published papers, one M.S. thesis and one Ph.D. dissertation. A list of these publications is included in the report.

2. DESCRIPTION OF THE RESEARCH

The initial efforts under the grant made use of an abstract quasi-linearization algorithm for parameter estimation in differential-delay models. An algorithm was developed and tested on a number of sample problems. These results were reported in [1]. The quasi-linearization algorithm worked very well and lead to a number of theoretical questions that remain under investigation.

In some applications involving aero-elastic phenomena, an appropriate a hereditary model involves singular type integro-differential equations. In order to construct state space models and develop approximations for identification, fundamental questions concerning the well-posedness of the models were studied. These results are given in [2], [6], [10] and [11]. The closely related problem of system realization was considered and reported on in [4]. These fundamental investigations are important in that they provide information needed in the development of approximation schemes. For example, "minimal realizations" should be used whenever possible in order to reduce the computational requirements of a numerical optimization scheme.

Once state space models were developed, attention was turned to the construction of numerical approximation schemes. Two approaches were considered. The first approach used splines to construct approximating systems and "Trotter-Kato" theorems to establish convergence of the algorithms. The second method was more direct and involved the approximation of the hereditary systems by difference equations. The parameter estimation problem was thus reduced to a nonlinear programming problem. Both approaches resulted in practical and efficient algorithms for parameter estimation.

Papers [3], [5] and [7] contain both theoretical and numerical results for the spline based approximating systems method. The finite difference method is presented along with numerical results in [8], [9] and the M.S. thesis [12].

Although much, of the initial work concentrated on linear systems, the methods were extended to nonlinear systems. The finite difference method worked very well on nonlinear problems (see [9]). Approximation techniques based on abstract nonlinear state space models were investigated in the Ph.D. dissertation [13]. The approximation schemes developed in [13] are applicable to a large class of nonlinear, neutral and retarded functional differential equations.

As a consequence of this research, a number of computational algorithms for parameter estimation in hereditary control systems were developed. These algorithms have been analyzed theoretically for convergence and tested on a number of numerical problems. They were extended to nonlinear systems, and are thus applicable to a large class of physical systems.

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